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TRANSITION CURVES.

A FIELD BOOK FOR ENGINEERS,

CONTAINING

RULES AND TABLES FOR LAYING OUT TRANSITION CURVES.

BY

WALTER G. FOX,

CIVIL ENGINEER.

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PREFACE.

In this work the endeavor has been to condense the essential facts and principles constituting the theory of the transition curve and to demonstrate how the curve can be conveniently laid out in field practice.

The same method has been adopted as is usually employed in running circular curves so that the field operations may be more readily comprehended and performed.

WALTER G. FOX.

NEW YORK, October 3d, 1893.

CHAPTER I.

Introduction.

Near the ends of a railway curve the curvature should be gradually diminished to enable trains at high speed to deviate gradually from the tangent and avoid any shock caused by changing too suddenly from a straight line to a sharp curve.

A transition curve is generally used to connect the circular curve with the tangent as it makes easy transition between them.

Moreover, as the outer rail of a curved track is elevated above the inner rail, a transition curve will unite better with the tangent; for the super elevation of the outer rail is proportional to the degree of curve which is least at the initial point.

CHAPTER II.

A transition curve is a compound curve with many changes of radius. It has nearly the form of the cubic parabola.

The curve is laid out on chords with the transit in the same manner as circular curves. A uniform chord length of 10 feet has been arbitrarily assumed to facilitate calculation, and the degree of curve changed at the end of every chord. The deflection angles have been computed and will be found in the tables.

To compute the deflection angles it was necessary to have the co-ordinates of every point of compound curve. The sines and cosines of the different angles between the tangent and the chords of the curves multiplied by 10 will give the required co-ordinates.

In Fig. I. T is the beginning of the curve. The distance measured along the tangent in the direction of L is the latitude and in the direction of D at a right angle

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Fig. 1.

with the tangent is the departure of the various points of compound curves.

For example let us refer to Table I., which begins with a 0° 10′ curve and compounds into a sharper curve at the end of each chord, the degree of curve changing to 0° 20′, 0° 30′, 0° 40′, etc. See Fig. 2.

Dist	Degree of curve.	Angle of chord.	Cosine x 10.	Sine x 10.	Co-ordinates	
					Latitude.	Departure.
10	0° 10′	0° 0′ 30″	10.000000	0.001454	10.000000	0.001454
20	0° 20′	0° 2′ 00″	9.999998	0.005818	19.999998	0.007272
30	0° 30′	0° 4′ 30″	9.999991	0.013090	29.999989	0.020362
40	0° 40′	0° 8′ 00″	9.999973	0.023271	39.999962	0.043633
50	0° 50′	0° 12′ 30″	9.999933	0.036361	49.999895	0.079994

Having calculated the co-ordinates of the different points the deflection angles were determined by

$$\frac{D}{L} = \text{tan. T.}$$

Example: To find the deflection angle for the first point in Table I.

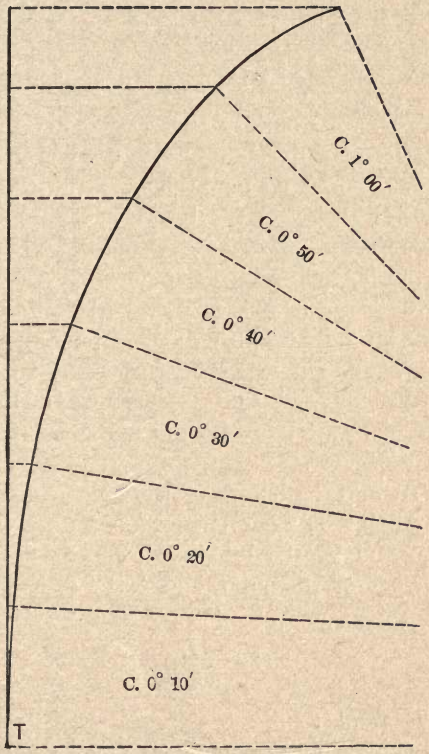

Fig. 2.

	Dep., 0.001454	log.	—3.1625644
	Lat., 10.000000	log.	1.0000000
Ans.	Def. angle, 0° 0′ 30″	log. tan.	6.1625644

The difference in the degree of curve between the different arcs of the transition curve should be maintained as nearly as possible between the terminating arc and the circular curve.

In the field the transit should be placed at T and the angles deflected from the tangent. In case there should be an obstacle making a point invisible at T, the next point should be measured on the long chord. The intermediate point can then be easily set.

To find the length of the long chord to any point on a curve, Fig. 3.

Let C be the length of chord, L the latitude of the point, and A the deflection angle.

$$C = \frac{L}{\cos A}$$

Example:

To find the length of the long chord to the 8th point of the curve in Table III.

Fig. 3.

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	Lat.	79.991	log.	1.9030411
	Def. angle,	0° 38′ 15″	log. cos.	9.9999731
Ans.	Long chord,	79.996	log.	1.9030680

CHAPTER III.

Explanation of Tables.

The curvature increases more rapidly in each succeeding table.

Table I. begins with a 0° 10′ curve which is the difference in curvature between the first arc of each table, the degrees of curve being 0° 10′, 0° 20′, 0° 30′, etc. The degree of curve of the first arc is equal to the difference between all the other arcs in the same table, so that the sixth arc in Table I. is a 1° curve and the sixth arc in Table VI. is a 6° curve.

Column I. gives the length of curve according to the central angle consumed which will be found on the same line in a different column, and also the other corresponding parts of the tables under their respective headings.

Column II. has the degree of curve of each separate arc.

Column III. contains the deflection angles. It will be observed that the value of the angles has been calculated to the nearest second. Such accuracy is not expected in practice but was necessary in order to correctly determine the long chords.

Column IV. gives the central angles of the curves.

Columns V. and VI. have the co-ordinates of every point of compound curve, By using the co-ordinates in place of the deflection angles the curve may be laid out with offsets from the tangent.

Column VII. has the long chords to every point on the curves.

Column VIII. contains numbers by which the tangents of half the intersection angles of the curves should be multiplied and the product added to the tangent distances as a correction.

CHAPTER IV.

Problems.

Given, a 5 degree curve, to run a transition curve connecting it with a tangent having an intersection angle of 20 degrees.

If we select the curve from Table VI. its length will be 40 feet, consisting of 4 arcs, and the central angle will be 1 degree. As this must be repeated at the other end of the curve, the central angle should be multiplied by 2 and the sum subtracted from the intersection angle. The remainder will be the central angle of the circular curve. To find its length divide the central angle by the degree of curve.

Example:

Intersection angle,	20°
Central angle of trans. curve × 2,	2°
	5/ 18°
Length of circular curve,	360 ft.

To find the tangent distance V.

Let M. be the length of circular curve that the central angle of transition curve consumes, a d the apex distance of circular curve and L the latitude of the terminal point of the transition curve.

$$V = ad + L - M.$$

Example:

Apex. dist. of 5° curve for 20°,	202.120
Lat. of ter'l point of trans. curve,	39.998
	242.118
Length of 5° curve to consume 1°,	20.000
Ans. V = Tan. distance,	222.118

A correction should be added to the product which will not materially change the result unless the length of curve exceeds 70 feet, or the intersection angle contains more than 50 degrees.

Rule: Multiply the tangent of half the intersection angle by the distance in column 8 corresponding to the terminal point of the curve.

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Example:

1/2 intersection angle = 10°

Tan. = .1763 × .086 = - .015

then V = - - - - 222.118

Correction - - - .015

Tan. dist. - - - 222.133

With curves of short radius there is a slight error in the preceding formula, as M does not always have exactly its true value. The error, however, is too small to take into account in field practice. In the above example it is only one-thousandth of a foot. In a ten degree curve the error is about three-tenths.

The true value of M can be determined by multiplying the cosine of half the central angle of transition curve by the length of circular curve it has consumed.

Example:

1/2 central angle of trans. curve = 0° 30′ log. cos. 9.9999835

Length of circular curve consumed = 20 feet log. 1.3010300

Ans. M. = 19.999 ft. log. 1.3010135

Having measured the tangent distances, the transition curves should be first laid out and then connected by running the circular curve. See Fig. 4.

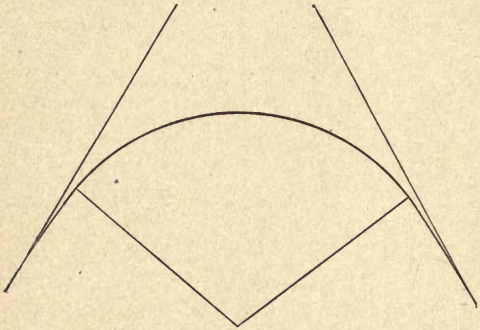

Fig. 4.

If there are two circular curves of different radii, their ends will be a short distance apart, the sharper curve being on the inner side, which can then be eased off to unite with the other curve. See Fig. 5.

On railway location it may be desirable to first lay out the circular curve, neglecting the transition curves until the time of construction.

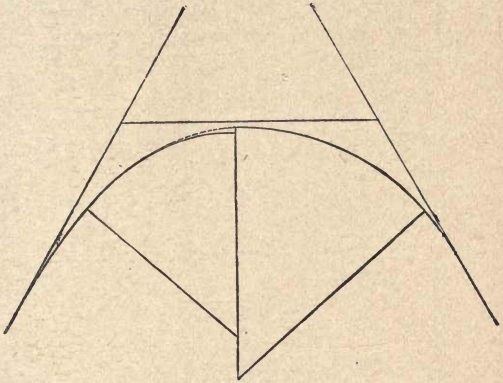

Fig. 5.

In this case the two terminal points of the transition curves should be located with their co-ordinates, the transit set over either point and a foresight taken on the other and the curve run in.

Compound curves should not be located in this manner, as a backsight is then required.

TRANSITION CURVE TABLES.

TABLE I.

Length of Curve.	Degree of Curve.	Deflection Angle.	Central Angle.	Co-ordinates		Long Chord.	Corr'n for Tang. Dist.
				Latitude.	Departure.		
10	0° 10′	0° 0′ 30″	0° 1′ 0″	10.000	0.001	10.000	.000
20	0° 20′	0° 1′ 12″	0° 3′ 0″	20.000	0.007	20.000	.004
30	0° 30′	0° 2′ 17″	0° 6′ 0″	30.000	0.020	30.000	.007
40	0° 40′	0° 3′ 41″	0° 10′ 0″	40.000	0.043	40.000	.014
50	0° 50′	0° 5′ 30″	0° 15′ 0″	50.000	0.080	50.000	.029
60	1° 00′	0° 7′ 33″	0° 21′ 0″	60.000	0.132	60.000	.045
70	1° 10′	0° 9′ 58″	0° 28′ 0″	69.999	0.203	69.999	.061
80	1° 20′	0° 12′ 43″	0° 36′ 0″	79.999	0.296	79.999	.086
90	1° 30′	0° 15′ 49″	0° 45′ 0″	89.998	0.414	89.999	.126
100	1° 40′	0° 19′ 15″	0° 55′ 0″	99.997	0.560	99.998	.168
110	1° 50′	0° 23′ 0″	1° 6′ 0″	109.995	0.736	109.997	.208
120	2° 00′	0° 27′ 4″	1° 18′ 0″	119.993	0.945	119.996	.265
130	2° 10′	0° 31′ 30″	1° 31′ 0″	129.990	1.191	129.995	.341
140	2° 20′	0° 36′ 15″	1° 45′ 0″	139.986	1.476	139.994	.417
150	2° 30′	0° 41′ 19″	2° 0′ 0″	149.981	1.803	149.992	.494
160	2° 40′	0° 46′ 44″	2° 16′ 0″	159.974	2.175	159.989	.593
170	2° 50′	0° 52′ 30″	2° 33′ 0″	169.965	2.596	169.985	.717
180	3° 00′	0° 58′ 35″	2° 51′ 0″	179.954	3.067	179.980	.843
190	3° 10′	1° 4′ 59″	3° 10′ 0″	189.940	3.591	189.974	.967
200	3° 20′	1° 11′ 45″	3° 30′ 0″	199.923	4.173	199.966	1.119
210	3° 30′	1° 18′ 50″	3° 51′ 0″	209.903	4.814	209.958	1.302
220	3° 40′	1° 26′ 14″	4° 13′ 0″	219.878	5.517	219.947	1.487
230	3° 50′	1° 34′ 0″	4° 36′ 0″	229.848	6.286	229.934	1.671
240	4° 00′	1° 42′ 5″	5° 0′ 0″	239.814	7.123	239.920	1.889

TABLE II.

Length of Curve.	Degree of Curve.	Deflection Angle.	Central Angle.	Co-ordinates		Long Chord.	Corr'n for Tang. Dist.
				Latitude.	Departure.		
10	0° 20′	0° 1′ 0″	0° 2′ 0″	10.000	0.003	10.000	.002
20	0° 40′	0° 2′ 24″	0° 6′ 0″	20.000	0.014	20.000	.005
30	1° 00′	0° 4′ 35″	0°12′ 0″	30.000	0.040	30.000	.014
40	1° 20′	0° 7′ 28″	0°20′ 0″	40.000	0.087	40.000	.029
50	1° 40′	0° 11′ 0″	0°30′ 0″	50.000	0.160	50.000	.051
60	2° 00′	0° 15′ 7″	0°42′ 0″	59.999	0.264	59.999	.081
70	2° 20′	0° 19′ 59″	0°56′ 0″	69.998	0.407	69.999	.122
80	2° 40′	0° 25′ 29″	1°12′ 0″	79.996	0.593	79.998	.174
90	3° 00′	0° 31′ 40″	1°30′ 0″	89.993	0.829	89.996	.240
100	3° 20′	0° 38′ 30″	1°50′ 0″	99.989	1.120	99.995	.320
110	3° 40′	0° 45′ 58″	2°12′ 0″	109.983	1.471	109.993	.415
120	4° 00′	0° 54′ 9″	2°36′ 0″	119.974	1.890	119.989	.529
130	4° 20′	1° 3′ 0″	3°02′ 0″	129.962	2.382	129.983	.662
140	4° 40′	1° 12′ 29″	3°30′ 0″	139.946	2.951	139.977	.813
150	5° 00′	1° 22′ 39″	4° 0′ 0″	149.924	3.605	149.967	.988
160	5° 20′	1° 33′ 29″	4°32′ 0″	159.897	4.349	159.956	1.185
170	5° 40′	1° 44′ 59″	5° 6′ 0″	169.861	5.189	169.940	1.407
180	6° 00′	1° 57′ 9″	5°42′ 0″	179.817	6.130	179.921	1.655
190	6° 20′	2° 9′ 58″	6°20′ 0″	189.762	7.178	189.897	1.930
200	6° 40′	2° 23′ 28″	7° 0′ 0″	199.694	8.339	199.868	2.234
210	7° 00′	2° 37 39″	7°42′ 0″	209.612	9.619	209.832	2.569
220	7° 20′	2° 52′ 28″	8°26′ 0″	219.513	11.022	219.789	2.934
230	7° 40′	3° 7′ 58″	9°12′ 0″	229.395	12.555	229.738	3.332
240	8° 00′	3° 24′ 6″	10° 0′ 0″	239.255	14.222	239.677	3.763

TABLE III.

Length of Curve.	Degree of Curve.	Deflection Angle.	Central Angle.	Co-ordinates		Long Chord.	Corr'n for Tang. Dist.
				Latitude.	Departure.		
10	0° 30′	0° 1′ 30″	0° 3′ 0″	10.000	0.004	10.000	.003
20	1° 00′	0° 3′ 47″	0° 9′ 0″	20.000	0.022	20.000	.010
30	1° 30′	0° 6′ 59″	0° 18′ 0″	30.000	0.061	30.000	.022
40	2° 00′	0° 11′ 15″	0° 30′ 0″	40.000	0.131	40.000	.044
50	2° 30′	0° 16′ 30″	0° 45′ 0″	49.999	0.240	49.999	.080
60	3° 00′	0° 22′ 45″	1° 3′ 0″	59.998	0.397	59.999	.126
70	3° 30′	0° 30′ 0″	1° 24′ 0″	69.995	0.611	69.997	.183
80	4° 00′	0° 38′ 15″	1° 48′ 0″	79.991	0.890	79.996	.262
90	4° 30′	0° 47′ 29″	2° 15′ 0″	89.985	1.243	89.993	.366
100	5° 00′	0° 57′ 44″	2° 45′ 0″	99.975	1.679	99.989	.487
110	5° 30′	1° 8′ 59″	3° 18′ 0″	109.962	2.207	109.984	.624
120	6° 00′	1° 21′ 14″	3° 54′ 0″	119.942	2.835	119.975	.793
130	6° 30′	1° 34′ 30″	4° 33′ 0″	129.915	3.572	129.964	1.001
140	7° 00′	1° 48′ 44″	5° 15′ 0″	139.878	4.426	139.948	1.231
150	7° 30′	2° 3′ 59″	6° 0′ 0″	149.830	5.406	149.927	1.480
160	8° 00′	2° 20′ 14″	6° 48′ 0″	159.768	6.521	159.901	1.776
170	8° 30′	2° 37′ 28″	7° 39′ 0″	169.688	7.778	169.866	2.130
180	9° 00′	2° 55′ 42″	8° 33′ 0″	179.589	9.187	179.824	2.491
190	9° 30′	3° 14′ 57″	9° 30′ 0″	189.465	10.756	189.770	2.889
200	10° 00′	3° 35′ 11″	10° 30′ 0″	199.313	12.492	199.704	3.342
210	10° 30′	3° 56′ 25″	11° 33′ 0″	209.128	14.405	209.623	3.855
220	11° 00′	4° 18′ 39″	12° 39′ 0″	218.906	16.501	219.527	4.399
230	11° 30′	4° 41′ 52″	13° 48′ 0″	228.641	18.789	229.411	4.973
240	12° 00′	5° 6′ 5″	15° 0′ 0″	238.327	21.276	239.275	5.612

TABLE IV.

Length of Curve.	Degree of Curve.	Deflection Angle.	Central Angle.	Co-ordinates		Long Chord.	Corr'n for Tang. Dist.
				Latitude.	Departure.		
10	0° 40′	0° 2′ 0″	0° 4′ 0″	10.000	0.006	10.000	.003
20	1° 20′	0° 4′ 59″	0° 12′ 0″	20.000	0.029	20.000	.012
30	2° 00′	0° 9′ 17″	0° 24′ 0″	30.000	0.081	30.000	.029
40	2° 40′	0° 14′ 57″	0° 40′ 0″	39.999	0.174	39.999	.058
50	3° 20′	0° 22′ 0″	1° 0′ 0″	49.998	0.320	49.999	.102
60	4° 00′	0° 30′ 19″	1° 24′ 0″	59.996	0.529	59.998	.162
70	4° 40′	0° 39′ 59″	1° 52′ 0″	69.992	0.814	69.996	.244
80	5° 20′	0° 50′ 58″	2° 24′ 0″	79.985	1.186	79.993	.348
90	6° 00′	1° 3′ 18″	3° 0′ 0″	89.974	1.657	89.989	.479
100	6° 40′	1° 16′ 59″	3° 40′ 0″	99.957	2.239	99.982	.639
110	7° 20′	1° 31′ 58″	4° 24′ 0″	109.932	2.942	109.971	.831
120	8° 00′	1° 48′ 19″	5° 12′ 0″	119.897	3.779	119.956	1.057
130	8° 40′	2° 5′ 59″	6° 04′ 0″	129.849	4.761	129.936	1.321
140	9° 20′	2° 24′ 58″	7° 0′ 0″	139.784	5.898	139.908	1.625
150	10° 00′	2° 45′ 18″	8° 0′ 0″	149.698	7.204	149.871	1.972
160	10° 40′	3° 6′ 58″	9° 4′ 0″	159.588	8.688	159.824	2.365
170	11° 20′	3° 29′ 57″	10° 12′ 0″	169.446	10.361	169.762	2 805
180	12° 00′	3° 54′ 15″	11° 24′ 0″	179.269	12.235	179.686	3.296
190	12° 40′	4° 19′ 54″	12° 40′ 0″	189.050	14.320	189.591	3.841
200	13° 20′	4° 46′ 52″	14° 0′ 0″	198.780	16.626	199.474	4.439
210	14° 00′	5° 15′ 9″	15° 24′ 0″	208.453	19.163	209.332	5.094
220	14° 40′	5° 44′ 45″	16° 52′ 0″	218.059	21.942	219.160	5.809
230	15° 20′	6° 15′ 41″	18° 24′ 0″	227.589	24.971	228.955	6.585
240	16° 00′	6° 47′ 56″	20° 0′ 0″	237.033	28.260	238.711	7.422

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TABLE V.

Length of Curve.	Degree of Curve.	Deflection Angle.	Central Angle.	Co-ordinates		Long Chord.	Corr'n for Tang. Dist.
				Latitude.	Departure.		
10	0° 50′	0° 2′ 30″	0° 5′ 0″	10.000	0.007	10.000	.004
20	1° 40′	0° 6′ 11″	0° 15′ 0″	20.000	0.036	20.000	.016
30	2° 30′	0° 11′ 41″	0° 30′ 0″	29.999	0.102	29.999	.037
40	3° 20′	0° 18′ 44″	0° 50′ 0″	39.999	0.218	39.999	.073
50	4° 10′	0° 27′ 30″	1° 15′ 0″	49.997	0.400	49.998	.131
60	5° 00′	0° 37′ 52″	1° 45′ 0″	59.994	0.661	59.997	.207
70	5° 50′	0° 50′ 0″	2° 20′ 0″	69.987	1.018	69.994	.305
80	6° 40′	1° 3′ 44″	3° 0′ 0″	79.977	1.483	79.990	.436
90	7° 30′	1° 19′ 10″	3° 45′ 0″	89.959	2.072	89.982	.606
100	8° 20′	1° 36′ 14″	4° 35′ 0″	99.933	2.798	99.972	.806
110	9° 10′	1° 54′ 59″	5° 30′ 0″	109.894	3.677	109.955	1.038
120	10° 00′	2° 15′ 23″	6° 30′ 0″	119.839	4.722	119.932	1.321
130	10° 50′	2° 37′ 28″	7° 35′ 0″	129.764	5.948	129.900	1.659
140	11° 40′	3° 1′ 13″	8° 45′ 0″	139.662	7.369	139.856	2.039
150	12° 30′	3° 26′ 37″	10° 0′ 0″	149.529	8.998	149.799	2.461
160	13° 20′	3° 53′ 41″	11° 20′ 0″	159.356	10.849	159.725	2.950
170	14° 10′	4° 22′ 24″	12° 45′ 0″	169.136	12.935	169.630	3.509
180	15° 00′	4° 52′ 46″	14° 15′ 0″	178.860	15.269	179.510	4.119
190	15° 50′	5° 24′ 48″	15° 50′ 0″	188.517	17.865	189.361	4.781
200	16° 40′	5° 58′ 29″	17° 30′ 0″	198.097	20.733	199.179	5.521
210	17° 30′	6° 33′ 49″	19° 15′ 0″	207.587	23.885	208.956	6.344
220	18° 20′	7° 10′ 47″	21° 5′ 0″	216.974	27.332	218.689	7.223
230	19° 10′	7° 49′ 23″	23° 0′ 0″	226.243	31.085	228.368	8.157
240	20° 00′	8° 29′ 39″	25° 0′ 0″	235.379	35.153	237.989	9.180

TABLE VI.

Length of Curve.	Degree of Curve.	Deflection Angle.	Central Angle.	Co-ordinates		Long Chord.	Corr'n for Tang. Dist.
				Latitude.	Departure.		
10	1° 00′	0° 3′ 0″	0° 6′ 0″	10.000	0.008	10.000	.004
20	2° 00′	0° 7′ 23″	0° 18′ 0″	20.000	0.043	20.000	.017
30	3° 00′	0° 13′ 58″	0° 36′ 0″	29.999	0.122	29.999	.043
40	4° 00′	0° 22′ 26″	1° 0′ 0″	39.998	0.261	39.999	.086
50	5° 00′	0° 33′ 0″	1° 30′ 0″	49.996	0.480	49.998	.153
60	6° 00′	0° 45′ 30″	2° 6′ 0″	59.991	0.794	59.996	.244
70	7° 00′	0° 59′ 58″	2° 48′ 0″	69.982	1.221	69.992	.366
80	8° 00′	1° 16′ 28″	3° 36′ 0″	79.966	1.779	79.985	.523
90	9° 00′	1° 35′ 0″	4° 30′ 0″	89.941	2.486	89.975	.719
100	10° 00′	1° 55′ 28″	5° 30′ 0″	99.903	3.357	99.959	.958
110	11° 00′	2° 17′ 58″	6° 36′ 0″	109.848	4.411	109.936	1.245
120	12° 00′	2° 42′ 29″	7° 48′ 0″	119.769	5.665	119.903	1 584
130	13° 00′	3° 8′ 57″	9° 06′ 0″	129.660	7.134	129.856	1.978
140	14° 00′	3° 37′ 26″	10° 30′ 0″	139.514	8.836	139.793	2.431
150	15° 00′	4° 7′ 55″	12° 00′ 0″	149.322	10.787	149.711	2.947
160	16° 00′	4° 40′ 23″	13° 36′ 0″	159.073	13.003	159.603	3.531
170	17° 00′	5° 14′ 49″	15° 18′ 0″	168.757	15.498	169.467	4.183
180	18° 00′	5° 51′ 15″	17° 06′ 0″	178.360	18.288	179.295	4.908
190	19° 00′	6° 29′ 39″	19° 0′ 0″	187.868	21.386	189.081	5.706
200	20° 00′	7° 10′ 2″	21° 0′ 0″	197.265	24.806	198.818	6.582
210	21° 00′	7° 52′ 24″	23° 6′ 0″	206.534	28.561	208.499	7.538
220	22° 00′	8° 36′ 42″	25° 18′ 0″	215.655	32.660	218.114	8.571
230	23° 00′	9° 22′ 58″	27° 36′ 0″	224.608	37.114	227.654	9.683
240	24° 00′	10° 11′ 10″	30° 0′ 0″	233.371	41.932	237.108	10.874

TABLE OF TANGENT DISTANCES

FOR

CIRCULAR RAILROAD CURVES.

This table contains the tangent distances to a 1 degree curve for every two minutes of intersection angle to 90 degrees.

The tangent distance to any other degree of curve may be determined by dividing the number corresponding to the intersection angle by the degree of curve.

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′	0°	1°	2°	3°	′
0	0.00	50.00	100.00	150.07	0
2	1.67	51.67	101.67	151.74	2
4	3.33	53.33	103 34	153.41	4
6	5.00	55.00	105.01	155.08	6
8	6.67	56.67	106.68	156.75	8
10	8.33	58.33	108.35	158.42	10
12	10.00	60.00	110.02	160.09	12
14	11.67	61.67	111.69	161.76	14
16	13.33	63.33	113.36	163.43	16
18	15.00	65.00	115.02	165.09	18
20	16.67	66.67	116.69	166.76	20
22	18.33	68.33	118.36	168.43	22
24	20.00	70.00	120.03	170.10	24
26	21.67	71.67	121.70	171.77	26
28	23.33	73.33	123.37	173.44	28
30	25.00	75.00	125.03	175.10	30
32	26.67	76.67	126.70	176.72	32
34	28.33	78.33	128.37	178.39	34
36	30.00	80.00	130.04	180.06	36
38	31.67	81.67	131.71	181.73	38
40	33.33	83.33	133.38	183.40	40
42	35.00	85.00	135.05	185.07	42
44	36.67	86.67	136.72	186.74	44
46	38.33	88.33	138.38	188.40	46
48	40.00	90.00	140.05	190.07	48
50	41.67	91.67	141.72	191.74	50
52	43.33	93.33	143.39	193.41	52
54	45.00	95.00	145.06	195.08	54
56	46.67	96.67	146.73	196.75	56
58	48.33	98.33	148.40	198.42	58
60	50.00	100.00	150.07	200.09	60

′	4°	5°	6°	7°	′
0	200.09	250.17	300.30	350.44	0
2	201.76	251.84	301.97	352.11	2
4	203.43	253.51	303.64	353.79	4
6	205.10	255.18	305.31	355.46	6
8	206.77	256.85	306.98	357.13	8
10	208.44	258.52	308.65	358.81	10
12	210.11	260.20	310.32	360.48	12
14	211.77	261.86	311.99	362.15	14
16	213.45	263.54	313.66	363.83	16
18	215.11	265.20	315.33	365.50	18
20	216.78	266.87	317.00	367.17	20
22	218.45	268.54	318.67	368.85	22
24	220.12	270.21	320.34	370.52	24
26	221.79	271.88	322.01	372.19	26
28	223.46	273.54	323.68	373.86	28
30	225.13	275.21	325.35	375.54	30
32	226.80	276.88	327.02	377.22	32
34	228.47	278.55	328.69	378.89	34
36	230.14	280.23	330.37	380.57	36
38	231.81	281.90	332.04	382.24	38
40	233.48	283.57	333.71	383.92	40
42	235.15	285.24	335.38	385.60	42
44	236.82	286.91	337.05	387.27	44
46	238.48	288.59	338.73	388.95	46
48	240.15	290.26	340.40	390.62	48
50	241.82	291.93	342.07	392.30	50
52	243.49	293.60	343.74	393.98	52
54	245.16	295.27	345.41	395.65	54
56	246.83	296.95	347.08	397.33	56
58	248.50	298.62	348.76	399.01	58
60	250.17	300.30	350.44	400.70	60

′	8°	9°	10°	11°	′
0	400.70	450.95	501.32	551.74	0
2	402.37	452.63	503.00	553.42	2
4	404.05	454.31	504.68	555.10	4
6	405.72	455.98	506.36	556.78	6
8	407.39	457.66	508.04	558.46	8
10	409.06	459.34	509.72	560.14	10
12	410.74	461.02	511.40	561.82	12
14	412.41	462.70	513.08	563.50	14
16	414.08	464.37	514.76	565.18	16
18	415.75	466.05	516.44	566.86	18
20	417.43	467.73	518.12	568.54	20
22	419.10	469.41	519.80	570.22	22
24	420.77	471.08	521.48	571.90	24
26	422.45	472.76	523.16	573.58	26
28	424.12	474.43	524.85	575.27	28
30	425.79	476.10	526.53	576.95	30
32	427.47	477.78	528.21	578.63	32
34	429.15	479.46	529.89	580.32	34
36	430.82	481.14	531.57	582.00	36
38	432.50	482.83	533.25	583.69	38
40	434.18	484.51	534.93	585.37	40
42	435.86	486.19	536.61	587.05	42
44	437.54	487.87	538.29	588.74	44
46	439.21	489.56	539.97	590.42	46
48	440.89	491.24	541.65	592.11	48
50	442.57	492.92	543.33	593.79	50
52	444.25	494.60	545.01	595.47	52
54	445.93	496.28	546.69	597.16	54
56	447.60	497.96	548.37	598.84	56
58	449.28	499.65	550.06	600.53	58
60	450.95	501.32	551.74	602.22	60

′	12°	13°	14°	15°	′
0	602.22	652.87	703.53	754.35	0
2	603.91	654.56	705.23	756.05	2
4	605.60	656.25	706.92	757.74	4
6	607.28	657.93	708.62	759.44	6
8	608.97	659.62	710.31	761.13	8
10	610.66	661.31	712.01	762.83	10
12	612.35	663.00	713.71	764.53	12
14	614.04	664.69	715.40	766.22	14
16	615.72	666.37	717.10	767.92	16
18	617.41	668.06	718.79	769.61	18
20	619.10	669.75	720.49	771.31	20
22	620.79	671.44	722.20	773.01	22
24	622.48	673.13	723.89	774.70	24
26	624.16	674.81	725.59	776.40	26
28	625.85	676.51	727.28	778.09	28
30	627.55	678.20	728.97	779.79	30
32	629.24	679.89	730.66	781.49	32
34	630·93	681.58	732.35	783.19	34
36	632.61	683.26	734.05	784.89	36
38	634.30	684.95	735.74	786.59	38
40	635.99	686.64	737.43	788.29	40
42	637.68	688.33	739.12	789.99	42
44	639.37	690.02	740.81	791.69	44
46	641.05	691.70	742.51	793.39	46
48	642.74	693.39	744.20	795.09	48
50	644.43	695.08	745.89	796.79	50
52	646.12	696.77	747.58	798.49	52
54	647.81	698.46	749.27	800.19	54
56	649.49	700.14	750.97	801.89	56
58	651.18	701.83	752.66	803.59	58
60	652.87	703.53	754.35	805.29	60

′	16°	17°	18°	19°	′
0	805.29	856.35	907.52	958.86	0
2	806.99	858.05	909.23	960.57	2
4	808.64	859.76	910.94	962.30	4
6	810.39	861.46	912.65	964.00	6
8	812.09	863.16	914.36	965.72	8
10	813.79	864.87	916.07	967.43	10
12	815.49	866.57	917.78	969.15	12
14	817.19	868.27	919.49	970.86	14
16	818.89	869.98	921.20	972.58	16
18	820.59	871.68	922.91	974.29	18
20	822.29	873.38	924.63	976.01	20
22	823.99	875.09	926.34	977.72	22
24	825.69	876.79	928.05	979.44	24
26	827.39	878.49	929.76	981.15	26
28	829.09	880.20	931.47	982.86	28
30	830.79	881.90	933.18	984.58	30
32	832.49	883.61	934.89	986.30	32
34	834.20	885.32	936.60	988.02	34
36	835.90	887.02	938.32	989.74	36
38	837.61	888.73	940.03	991.46	38
40	839.31	890.44	941.74	993.18	40
42	841.01	892.15	943.45	994.90	42
44	842.72	893.86	945.16	996.62	44
46	844.42	895.56	946.88	998.34	46
48	846.13	897.27	948.59	1000.0	48
50	847.83	898.98	950.30	1001.8	50
52	849.53	900.69	952.01	1003.5	52
54	851.24	902.40	953.72	1005.2	54
56	852.94	904.10	955.44	1006.9	56
58	854.65	905.81	957.15	1008.6	58
60	856.35	907.52	958.86	1010.4	60

′	20°	21°	22°	23°	′
0	1010.4	1062.0	1113.8	1165.8	0
2	1012.1	1063.7	1115.5	1167.5	2
4	1013.8	1065.4	1117.3	1169.2	4
6	1015.5	1067.2	1119.0	1171.0	6
8	1017.2	1068.9	1120.7	1172.7	8
10	1019.0	1070.6	1122.4	1174.4	10
12	1020.7	1072.4	1124.2	1176.2	12
14	1022.4	1074.1	1125.9	1177.9	14
16	1024.1	1075.8	1127.6	1179.7	16
18	1025.8	1077.5	1129.4	1181.4	18
20	1027.6	1079.3	1131.1	1183.1	20
22	1029.3	1081.0	1132.8	1184.9	22
24	1031.0	1082.7	1134.6	1186.6	24
26	1032.7	1084.4	1136.3	1188.4	26
28	1034.4	1086.2	1138.0	1190.1	28
30	1036.1	1087.9	1139.7	1191.8	30
32	1037.9	1089.6	1141.5	1193.6	32
34	1039.6	1091.3	1143.2	1195.3	34
36	1041.3	1093.1	1144.9	1197.1	36
38	1043.0	1094.8	1146.7	1198.8	38
40	1044.8	1096.5	1148.4	1200.5	40
42	1046.5	1098.3	1150.1	1202.3	42
44	1048.2	1100.0	1151.9	1204.0	44
46	1049.9	1101.7	1153.6	1205.8	46
48	1051.7	1103.4	1155.4	1207.5	48
50	1053.4	1105.2	1157.1	1209.2	50
52	1055.1	1106.9	1158.8	1211.0	52
54	1056.8	1108.6	1160.6	1212.7	54
56	1058.6	1110.3	1162.3	1214.5	56
58	1060.3	1112.1	1164.0	1216.2	58
60	1062.0	1113.8	1165.8	1218.0	60

′	24°	25°	26°	27°	′
0	1218.0	1270.3	1322.9	1375.6	0
2	1219.7	1272.0	1324.6	1377.4	2
4	1221.4	1273.8	1326.4	1379.2	4
6	1223.2	1275.5	1328.1	1380.9	6
8	1224.9	1277.3	1329.9	1382.7	8
10	1226.7	1279.0	1331.6	1384.5	10
12	1228.4	1280.8	1333.4	1386.2	12
14	1230.2	1282.5	1335.2	1388.0	14
16	1231.9	1284.3	1336.9	1389.8	16
18	1233.6	1286.1	1338.7	1391.5	18
20	1235.4	1287.8	1340.4	1393.3	20
22	1237.1	1289.6	1342.2	1395.0	22
24	1238.9	1291.3	1343.9	1396.8	24
26	1240.6	1293.1	1345.7	1398.6	26
28	1242.4	1294.8	1347.4	1400.3	28
30	1244.1	1296.6	1349.2	1402.1	30
32	1245.8	1298.3	1351.0	1403.9	32
34	1247.6	1300.1	1352.7	1405.6	34
36	1249.3	1301.8	1354.5	1407.4	36
38	1251.1	1303.6	1356.2	1409.2	38
40	1252.8	1305.3	1358.0	1410.9	40
42	1254.6	1307.1	1359.8	1412.7	42
44	1256.3	1308.8	1361.5	1414.5	44
46	1258.1	1310.6	1363.3	1416.3	46
48	1259.8	1312.4	1365.1	1418.0	48
50	1261.5	1314.1	1366.8	1419.8	50
52	1263.3	1315.9	1368.6	1421.6	52
54	1265.0	1317.6	1370.4	1423.3	54
56	1266.8	1319.4	1372.1	1425.1	56
58	1268.5	1321.1	1373.9	1426.9	58
60	1270.3	1322.9	1375.6	1428.6	60

′	28°	29°	30°	31°	′
0	1428.6	1481.9	1535.3	1589.0	0
2	1430.4	1483.7	1537.1	1590.8	2
4	1432.2	1485.4	1538.9	1592.6	4
6	1434.0	1487.2	1540.7	1594.4	6
8	1435.7	1489.0	1542.5	1596.2	8
10	1437.5	1490.8	1544.3	1598.0	10
12	1439.3	1492.6	1546.0	1599.8	12
14	1441.1	1494.3	1547.8	1601.6	14
16	1442.8	1496.1	1549.6	1603.4	16
18	1444.6	1497.9	1551.4	1605.2	18
20	1446.4	1499.7	1553.2	1607.0	20
22	1448.2	1501.5	1555.0	1608.8	22
24	1449.9	1503.2	1556.8	1610.6	24
26	1451.7	1505.0	1558.6	1612.4	26
28	1453.5	1506.8	1560.4	1614.2	28
30	1455.2	1508.6	1562.2	1616.0	30
32	1457.0	1510.4	1564.0	1617.8	32
34	1458.8	1512.1	1565.7	1619.6	34
36	1460.6	1513.9	1567.5	1621.4	36
38	1462.3	1515.7	1569.3	1623.2	38
40	1464.1	1517.5	1571.1	1625.0	40
42	1465.9	1519.3	1572.9	1626.8	42
44	1467.7	1521.0	1574.7	1628.6	44
46	1469.5	1522.8	1576.5	1630.5	46
48	1471.2	1524.6	1578.3	1632.3	48
50	1473.0	1526.4	1580.1	1634.1	50
52	1474.8	1528.2	1581.9	1635.9	52
54	1476.6	1530.0	1583.7	1637.7	54
56	1478.3	1531.7	1585.5	1639.5	56
58	1480.1	1533.5	1587.2	1641.3	58
60	1481.9	1535.3	1589.0	1643.1	60

′	32°	33°	34°	35°	′
0	1643.1	1697.3	1751.8	1806.7	0
2	1644.9	1699.1	1753.7	1808.5	2
4	1646.7	1700.9	1755.5	1810.3	4
6	1648.5	1702.7	1757.3	1812.2	6
8	1650.3	1704.5	1759.1	1814.0	8
10	1652.1	1706.4	1761.0	1815.8	10
12	1653.9	1708.2	1762.8	1817.7	12
14	1655.7	1710.0	1764.6	1819.5	14
16	1657.5	1711.8	1766.4	1821.3	16
18	1659.3	1713.6	1768.3	1823.2	18
20	1661.1	1715.5	1770.1	1825.0	20
22	1662.9	1717.3	1771.9	1826.8	22
24	1664.7	1719.1	1773.7	1828.7	24
26	1666.5	1720.9	1775.6	1830.5	26
28	1668.3	1722.7	1777.4	1832.3	28
30	1670.1	1724.6	1779.2	1834.2	30
32	1671.9	1726.4	1781.0	1836.0	32
34	1673.7	1728.2	1782.9	1837.8	34
36	1675.5	1730.0	1784.7	1839.7	36
38	1677.4	1731.8	1786.5	1841.5	38
40	1679.2	1733.6	1788.4	1843.4	40
42	1681.0	1735.5	1790.2	1845.2	42
44	1682.8	1737.3	1792.0	1847.1	44
46	1684.6	1739.1	1793.9	1848.9	46
48	1686.4	1740.9	1795.7	1850.7	48
50	1688.2	1742.7	1797.5	1852.6	50
52	1690.0	1744.6	1799.3	1854.4	52
54	1691.8	1746.4	1801.2	1856.3	54
56	1693.7	1748.2	1803.0	1858.1	56
58	1695.5	1750.0	1804.8	1859.9	58
60	1697.3	1751.8	1806.7	1861.8	60

′	36°	37°	38°	39°	′
0	1861.8	1917.3	1973.0	2029.1	0
2	1863.6	1919.1	1974.9	2031.0	2
4	1865.5	1921.0	1976.7	2032.9	4
6	1867.3	1922.8	1978.6	2034.7	6
8	1869.2	1924.7	1980.5	2036.6	8
10	1871.0	1926.5	1982.3	2038.5	10
12	1872.9	1928.4	1984.2	2040.4	12
14	1874.7	1930.2	1986.1	2042.3	14
16	1876.5	1932.1	1987.9	2044.1	16
18	1878.4	1933.9	1989.8	2046.0	18
20	1880.2	1935.8	1991.7	2047.9	20
22	1882.1	1937.6	1993.6	2049.8	22
24	1883.9	1939.5	1995.4	2051.7	24
26	1885.8	1941.3	1997.3	2053.5	26
28	1887.6	1943.2	1999.2	2055.4	28
30	1889.5	1945.0	2001.0	2057.3	30
32	1891.3	1946.9	2002.9	2059.2	32
34	1893·2	1948.8	2004.8	2061.1	34
36	1895.0	1950.6	2006.6	2063.0	36
38	1896.9	1952.5	2008.5	2064.8	38
40	1898.7	1954.4	2010.4	2066.7	40
42	1900.6	1956.2	2012.3	2068.6	42
44	1902.4	1958.1	2014.1	2070.5	44
46	1904.3	1960.0	2016.0	2072.4	46
48	1906.1	1961.8	2017.9	2074.2	48
50	1908.0	1963.7	2019.7	2076.1	50
52	1909.8	1965.5	2021.6	2078.0	52
54	1911.7	1967.4	2023.5	2079.9	54
56	1913.5	1969.3	2025.4	2081.8	56
58	1915.4	1971.1	2027.2	2083.7	58
60	1917.3	1973.0	2029.1	2085.5	60

′	40°	41°	42°	43°	′
0	2085.5	2142.3	2199.5	2257.1	0
2	2087.4	2144.2	2201.4	2259.0	2
4	2089.3	2146.1	2203.3	2261.0	4
6	2091.2	2148.0	2205.3	2262.9	6
8	2093.1	2149.9	2207.2	2264.8	8
10	2095.0	2151.9	2209.1	2266.7	10
12	2096.9	2153.8	2211.0	2268.7	12
14	2098.8	2155.7	2212.9	2270.6	14
16	2100.7	2157.6	2214.9	2272.5	16
18	2102.6	2159.5	2216.8	2274.5	18
20	2104.5	2161.4	2218.7	2276.4	20
22	2106.3	2163.3	2220.6	2278.3	22
24	2108.2	2165.2	2222.5	2280.2	24
26	2110.1	2167.1	2224.4	2282.2	26
28	2112.0	2169.0	2226.4	2284.1	28
30	2113.9	2170.9	2228.3	2286.0	30
32	2115.8	2172.8	2230.2	2288.0	32
34	2117.7	2174.7	2232.1	2289.9	34
36	2119.6	2176.6	2234.0	2291.8	36
38	2121.5	2178.5	2236.0	2293.8	38
40	2123.4	2180.4	2237.9	2295.7	40
42	2125.3	2182.4	2239.8	2297.7	42
44	2127.2	2184.3	2241.7	2299.6	44
46	2129.1	2186.2	2243.6	2301.5	46
48	2131.0	2188.1	2245.6	2303.5	48
50	2132.9	2190.0	2247.5	2305.4	50
52	2134.7	2191.9	2249.4	2307.3	52
54	2136.6	2193.8	2251.3	2309.3	54
56	2138.5	2195.7	2253.3	2311.2	56
58	2140.4	2197.6	2255.2	2313.1	58
60	2142.3	2199.5	2257.1	2315.1	60

′	44°	45°	46°	47°	′
0	2315.1	2373.4	2432.2	2491.5	0
2	2317.0	2375.4	2434.2	2493.4	2
4	2319.0	2377.3	2436.1	2495.4	4
6	2320.9	2379.3	2438.1	2497.4	6
8	2322.8	2381.2	2440.1	2499.4	8
10	2324.8	2383.2	2442.1	2501.4	10
12	2326.7	2385.2	2444.0	2503.4	12
14	2328.7	2387.1	2446.0	2505.4	14
16	2330.6	2389.1	2448.0	2507.3	16
18	2332.6	2391.0	2449.9	2509.3	18
20	2334.5	2393.0	2451.9	2511.3	20
22	2336.4	2394.9	2453.9	2513.3	22
24	2338.4	2396.9	2455.9	2515.3	24
26	2340.3	2398.8	2457.8	2517.3	26
28	2342.3	2400.8	2459.8	2519.3	28
30	2344.2	2402.8	2461.8	2521.2	30
32	2346.1	2404.7	2463.8	2523.2	32
34	2348.1	2406.7	2465.7	2525.2	34
36	2350.0	2408.6	2467.7	2527.2	36
38	2352.0	2410.6	2469.7	2529.2	38
40	2353.9	2412.6	2471.7	2531.2	40
42	2355.9	2414.5	2473.6	2533.2	42
44	2357.8	2416.5	2475.6	2535.2	44
46	2359.8	2418.5	2477.6	2537.2	46
48	2361.7	2420.4	2479.6	2539.2	48
50	2363.7	2422.4	2481.6	2541.2	50
52	2365.6	2424.4	2483.5	2543.1	52
54	2367.6	2426.3	2485.5	2545.1	54
56	2369.5	2428.3	2487.5	2547.1	56
58	2371.5	2430.2	2489.5	2549.1	58
60	2373.4	2432.2	2491.5	2551.1	60

′	48°	49°	50°	51°	′
0	2551.1	2611.3	2671.9	2733.0	0
2	2553.1	2613.3	2673.9	2735.1	2
4	2555.1	2615.3	2676.0	2737.1	4
6	2557.1	2617.3	2678.0	2739.2	6
8	2559.1	2619.3	2680.0	2741.2	8
10	2561.1	2621.4	2682.1	2743.3	10
12	2563.1	2623.4	2684.1	2745.3	12
14	2565.1	2625.4	2686.1	2747.4	14
16	2567.1	2627.4	2688.2	2749.4	16
18	2569.1	2629.4	2690.2	2751.5	18
20	2571.1	2631.4	2692.3	2753.5	20
22	2573.1	2633.5	2694.3	2755.6	22
24	2575.1	2635.5	2696.3	2757.7	24
26	2577.1	2637.5	2698.4	2759.7	26
28	2579.1	2639.5	2700.4	2761.8	28
30	2581.1	2641.5	2702.4	2763.8	30
32	2583.1	2643.5	2704.5	2765.9	32
34	2585.1	2645.6	2706.5	2767.9	34
36	2587.2	2647.6	2708.6	2770.0	36
38	2589.2	2649.6	2710.6	2772.0	38
40	2591.2	2651.6	2712.6	2774.1	40
42	2593.2	2653.7	2714.7	2776.2	42
44	2595.2	2655.7	2716.7	2778.2	44
46	2597.2	2657.7	2718.8	2780.3	46
48	2599.2	2659.7	2720.8	2782.3	48
50	2601.2	2661.8	2722.8	2784.4	50
52	2603.2	2663.8	2724.9	2786.4	52
54	2605.2	2665.8	2726.9	2788.5	54
56	2607.2	2667.8	2729.0	2790.6	56
58	2609.3	2669.9	2731.0	2792.6	58
60	2611.3	2671.9	2733.0	2794.7	60

′	52°	53°	54°	55°	′
0	2794.7	2856.9	2919.5	2982.8	0
2	2796.8	2858.9	2921.6	2984.9	2
4	2798.8	2861.0	2923.8	2987.1	4
6	2800.9	2863.1	2925.9	2989.2	6
8	2803.0	2865.2	2928.0	2991.3	8
10	2805.0	2867.3	2930.1	2993.4	10
12	2807.1	2869.4	2932.2	2995.5	12
14	2809.2	2871.5	2934.3	2997.7	14
16	2811.2	2873.5	2936.4	2999.8	16
18	2813.3	2875.6	2938.5	3001.9	18
20	2815.4	2877.7	2940.6	3004.0	20
22	2817.4	2879.8	2942.7	3006.2	22
24	2819.5	2881.9	2944.8	3008.3	24
26	2821.6	2884.0	2946.9	3010.4	26
28	2823.6	2886.1	2949.0	3012.5	28
30	2825.7	2888.1	2951.1	3014.7	30
32	2827.8	2890.2	2953.2	3016.8	32
34	2829.8	2892.3	2955.3	3018.9	34
36	2831.9	2894.4	2957.5	3021.1	36
38	2834.0	2896.5	2959.6	3023.2	38
40	2836.1	2898.6	2961.7	3025.3	40
42	2838.2	2900.7	2963.8	3027.5	42
44	2840.2	2902.8	2965.9	3029.6	44
46	2842.3	2904.9	2968.0	3031.7	46
48	2844.4	2907.0	2970.1	3033.8	48
50	2846.5	2909.1	2972.2	3036.0	50
52	2848.5	2911.2	2974.4	3038.1	52
54	2850.6	2913.3	2976.5	3040.2	54
56	2852.7	2915.4	2978.6	3042.4	56
58	2854.8	2917.5	2980.7	3044.5	58
60	2856.9	2919.5	2982.8	3046.6	60

REESE LIBRARY OF THE UNIVERSITY OF CALIFORNIA

′	56°	57°	58°	59°	′
0	3046.6	3111.1	3176.1	3241.9	0
2	3048.8	3113.3	3178.3	3244.1	2
4	3050.9	3115.4	3180.5	3246.3	4
6	3053.1	3117.6	3182.7	3248.5	6
8	3055.2	3119.7	3184.9	3250.7	8
10	3057.4	3121.9	3187.1	3252.9	10
12	3059.5	3124.1	3189.2	3255.1	12
14	3061.6	3126.2	3191.4	3257.3	14
16	3063.8	3128.4	3193.6	3259.5	16
18	3065.9	3130.6	3195.8	3261.7	18
20	3068.1	3132.7	3198.0	3263.9	20
22	3070.2	3134.9	3200.2	3266.1	22
24	3072.4	3137.0	3202.4	3268.3	24
26	3074.5	3139.2	3204.5	3270.5	26
28	3076.6	3141.4	3206.7	3272.7	28
30	3078.8	3143.5	3208.9	3274.9	30
32	3080.9	3145.7	3211.1	3277.1	32
34	3083.1	3147·9	3213.3	3279.4	34
36	3085.2	3150.0	3215.5	3281.6	36
38	3087.4	3152.2	3217.7	3283.8	38
40	3089.6	3154.4	3219.9	3286.0	40
42	3091.7	3156.6	3222.1	3288.2	42
44	3093.9	3158.7	3224.3	3290.5	44
46	3096.0	3160.9	3226.5	3292.7	46
48	3098.2	3163.1	3228.7	3294.9	48
50	3100.3	3165.3	3230.9	3297.1	50
52	3102.5	3167.4	3233.1	3299.3	52
54	3104.6	3169.6	3235.3	3301.5	54
56	3106.8	3171.8	3237.5	3303.8	56
58	3108.9	3174.0	3239.7	3306.0	58
60	3111.1	3176.1	3241.9	3308.2	60

′	60°	61°	62°	63°	′
0	3308.2	3375.2	3442.9	3511.3	0
2	3310.4	3377.4	3445.2	3513.6	2
4	3312.7	3379.7	3447.5	3515.9	4
6	3314.9	3381.9	3449.7	3518.2	6
8	3317.1	3384.2	3452.0	3520.5	8
10	3319.3	3386.4	3454.3	3522.8	10
12	3321.6	3388.7	3456.6	3525.1	12
14	3323.8	3390.9	3458.8	3527.4	14
16	3326.0	3393.2	3461.1	3529.7	16
18	3328.3	3395.4	3463.4	3532.0	18
20	3330.5	3397.7	3465.7	3534.3	20
22	3332.7	3399.9	3467.9	3536.6	22
24	3334.9	3402.2	3470.2	3538.9	24
26	3337.2	3404.4	3472.5	3541.2	26
28	3339.4	3406.7	3474.7	3543.5	28
30	3341.6	3408.9	3477.0	3545.8	30
32	3343.9	3411.2	3479.3	3548.1	32
34	3346.1	3413.5	3481.6	3550.4	34
36	3348.3	3415.7	3483.9	3552.7	36
38	3350.6	3418.0	3486.2	3555.0	38
40	3352.8	3420.3	3488.5	3557.3	40
42	3355.0	3422.5	3490.7	3559.6	42
44	3357.3	3424.8	3493.0	3562.0	44
46	3359.5	3427.1	3495.3	3564.3	46
48	3361.8	3429.3	3497.6	3566.6	48
50	3364.0	3431.6	3499.9	3568.9	50
52	3366.2	3433.9	3502.2	3571.2	52
54	3368.5	3436.1	3504.5	3573.5	54
56	3370.7	3438.4	3506.8	3575.8	56
58	3373.0	3440.7	3509.0	3578.1	58
60	3375.2	3442.9	3511.3	3580.4	60

′	64°	65°	66°	67°	′
0	3580.4	3650.4	3721.1	3792.6	0
2	3582.8	3652.8	3723.4	3795.0	2
4	3585.1	3655.1	3725.8	3797.4	4
6	3587.4	3657.5	3728.2	3799.8	6
8	3589.7	3659.8	3730.6	3802.2	8
10	3592.1	3662.2	3732.9	3804.6	10
12	3594.4	3664.5	3735.3	3807.0	12
14	3596.7	3666.9	3737.7	3809.4	14
16	3599.1	3669.2	3740.1	3811.8	16
18	3601.4	3671.6	3742.4	3814.2	18
20	3603.7	3673.9	3744.8	3816.6	20
22	3606.0	3676.2	3747.2	3819.0	22
24	3608.4	3678.6	3749.6	3821.4	24
26	3610.7	3680.9	3751.9	3823.8	26
28	3613.0	3683.3	3754.3	3826.2	28
30	3615.3	3685.6	3756.7	3828.6	30
32	3617.7	3688.0	3759.1	3831.0	32
34	3620.0	3690.4	3761.5	3833.4	34
36	3622.3	3692.7	3763.9	3835.9	36
38	3624.7	3695.1	3766.3	3838.3	38
40	3627.0	3697.4	3768.7	3840.7	40
42	3629.4	3699.8	3771.0	3843.1	42
44	3631.7	3702.2	3773.4	3845.5	44
46	3634.0	3704.5	3775.8	3847.9	46
48	3636.4	3706.9	3778.2	3850.4	48
50	3638.7	3709.3	3780.6	3852.8	50
52	3641.1	3711.6	3783.0	3855.2	52
54	3643.4	3714.0	3785.4	3857.6	54
56	3645.7	3716.3	3787.8	3860.0	56
58	3648.1	3718.7	3790.2	3862.5	58
60	3650.4	3721.1	3792.6	3864.9	60

′	68°	69°	70°	71°	′
0	3864.9	3938.1	4012.1	4087.1	0
2	3867.3	3940.6	4014.6	4089.7	2
4	3869.7	3943.0	4017.1	4092.2	4
6	3872.2	3945.5	4019.6	4094.7	6
8	3874.6	3947.9	4022.1	4097.2	8
10	3877.0	3950.4	4024.6	4099.8	10
12	3879.5	3952.9	4027.1	4102.3	12
14	3881.9	3955.3	4029.6	4104.8	14
16	3884.3	3957.8	4032.1	4107.3	16
18	3886.8	3960.2	4034.6	4109.8	18
20	3889.2	3962.7	4037.1	4112.4	20
22	3891.6	3965.2	4039.6	4114.9	22
24	3894.1	3967.6	4042.1	4117.4	24
26	3896.5	3970.1	4044.6	4119.9	26
28	3898.9	3972.5	4047.1	4122.4	28
30	3901.4	3975.0	4049.6	4125.0	30
32	3903.8	3977.5	4052.1	4127.5	32
34	3906.3	3980.0	4054.6	4130.0	34
36	3908.7	3982.4	4057.1	4132.6	36
38	3911.2	3984.9	4059.6	4135.1	38
40	3913.6	3987.4	4062.1	4137.7	40
42	3916.1	3989.9	4064.6	4140.2	42
44	3918.5	3992.3	4067.1	4142.7	44
46	3921.0	3994.8	4069.6	4145.3	46
48	3923.4	3997.3	4072.1	4147.8	48
50	3925.9	3999.8	4074.6	4150.4	50
52	3928.3	4002.2	4077.1	4152.9	52
54	3930.8	4004.7	4079.6	4155.4	54
56	3933.2	4007.2	4082.1	4158.0	56
58	3935.7	4009.7	4084.6	4160.5	58
60	3938.1	4012.1	4087.1	4163.1	60

′	72°	73°	74°	75°	′
0	4163.1	4240.0	4317.8	4396.7	0
2	4165.6	4242.6	4320.5	4399.4	2
4	4168.2	4245.1	4323.1	4402.1	4
6	4170.7	4247.7	4325.7	4404.7	6
8	4173.3	4250.3	4328.3	4407.4	8
10	4175.8	4252.9	4330.9	4410.0	10
12	4178.4	4255.5	4333.6	4412.7	12
14	4181.0	4258.1	4336.2	4415.3	14
16	4183.5	4260.7	4338.8	4418.0	16
18	4186.1	4263.2	4341.4	4420.7	18
20	4188.6	4265.8	4344.0	4423.3	20
22	4191.2	4268.4	4346.7	4426.0	22
24	4193.7	4271.0	4349.3	4428.6	24
26	4196.3	4273.6	4351.9	4431.3	26
28	4198.8	4276.2	4354.5	4434.0	28
30	4201.4	4278.8	4357.1	4436.6	30
32	4204.0	4281.4	4359.8	4439.3	32
34	4206.5	4284.0	4362.4	4442.0	34
36	4209.1	4286.6	4365.1	4444.6	36
38	4211.7	4289.2	4367.7	4447.3	38
40	4214.3	4291.8	4370.3	4450.0	40
42	4216.8	4294.4	4373.0	4452.7	42
44	4219.4	4297.0	4375.6	4455.3	44
46	4222.0	4299.6	4378.3	4458.0	46
48	4224.5	4302.2	4380.9	4460.7	48
50	4227.1	4304.8	4383.5	4463.4	50
52	4229.7	4307.4	4386.2	4466.0	52
54	4232.3	4310.0	4388.8	4468.7	54
56	4234.8	4312.6	4391.5	4471.4	56
58	4237.4	4315.2	4394.1	4474.1	58
60	4240.0	4317.8	4396.7	4476.7	60

′	76°	77°	78°	79°	′
0	4476.7	4557.8	4640.0	4723.4	0
2	4479.4	4560.5	4642.8	4726.2	2
4	4482.1	4563.3	4645.6	4729.0	4
6	4484.8	4566.0	4648.3	4731.8	6
8	4487.5	4568.7	4651.1	4734.7	8
10	4490.2	4571.5	4653.9	4737.5	10
12	4492.9	4574.2	4656.7	4740.3	12
14	4495.6	4576.9	4659.4	4743.1	14
16	4498.3	4579.7	4662.2	4745.9	16
18	4501.0	4582.4	4665.0	4748.7	18
20	4503.7	4585.1	4667.7	4751.5	20
22	4506.3	4587.9	4670.5	4754.3	22
24	4509.0	4590.6	4673.3	4757.1	24
26	4511.7	4593.3	4676.0	4760.0	26
28	4514.4	4596.0	4678.8	4762.8	28
30	4517.1	4598.8	4681.6	4765.6	30
32	4519.8	4601.5	4684.4	4768.4	32
34	4522.5	4604.3	4687.2	4771.2	34
36	4525.3	4607.0	4689.9	4774.1	36
38	4528.0	4609.8	4692.7	4776.9	38
40	4530.7	4612.5	4695.5	4779.7	40
42	4533.4	4615.3	4698.3	4782.6	42
44	4536.1	4618.0	4701.1	4785.4	44
46	4538.8	4620.8	4703.9	4788.2	46
48	4541.5	4623.5	4706.7	4791.0	48
50	4544.2	4626.3	4709.5	4793.9	50
52	4547.0	4629.0	4712.2	4796.7	52
54	4549.7	4631.8	4715.0	4799.5	54
56	4552.4	4634.5	4717.8	4802.4	56
58	4555.1	4637.3	4720.6	4805.2	58
60	4557.8	4640.0	4723.4	4808.0	60

′	80°	81°	82°	83°	′
0	4808.0	4893.9	4981.0	5069.4	0
2	4810.9	4896.8	4983.9	5072.4	2
4	4813.7	4899.7	4986.8	5075.4	4
6	4816.6	4902.6	4989.8	5078.4	6
8	4819.4	4905.4	4992.7	5081.4	8
10	4822.3	4908.3	4995.7	5084.4	10
12	4825.1	4911.2	4998.6	5087.3	12
14	4828.0	4914.1	5001.5	5090.3	14
16	4830.8	4917.0	5004.5	5093.3	16
18	4833.7	4919.9	5007.4	5096.3	18
20	4836.5	4922.8	5010.3	5099.3	20
22	4839.4	4925.7	5013.3	5102.3	22
24	4842.2	4928.6	5016.2	5105.2	24
26	4845.1	4931.5	5019.2	5108.2	26
28	4847.9	4934.4	5022.1	5111.2	28
30	4850.8	4937.2	5025.0	5114.2	30
32	4853.7	4940.2	5028.0	5117.2	32
34	4856.5	4943.1	5031.0	5120.2	34
36	4859.4	4946.0	5033.9	5123.2	36
38	4862.3	4948.9	5036.9	5126.2	38
40	4865.1	4951.8	5039.8	5129.2	40
42	4868.0	4954.7	5042.8	5132.2	42
44	4870.9	4957.6	5045.8	5135.2	44
46	4873.8	4960.6	5048.7	5138.2	46
48	4876.6	4963.5	5051.7	5141.2	48
50	4879.5	4966.4	5054.6	5144.3	50
52	4882.4	4969.3	5057.6	5147.3	52
54	4885.3	4972.2	5060.6	5150.3	54
56	4888.1	4975.1	5063.5	5153.3	56
58	4891.0	4978.0	5066.5	5156.3	58
60	4893.9	4981.0	5069.4	5159.3	60

′	84°	85°	86°	87°	′
0	5159.3	5250.6	5343.3	5437.5	0
2	5162.3	5253.6	5346.4	5440.7	2
4	5165.3	5256.7	5349.5	5443.9	4
6	5168.4	5259.8	5352.7	5447.1	6
8	5171.4	5262.9	5355.8	5450.3	8
10	5174.4	5266.0	5358.9	5453.4	10
12	5177.5	5269.0	5362.0	5456.6	12
14	5180.5	5272.1	5365.2	5459.8	14
16	5183.5	5275.2	5368.3	5463.0	16
18	5186.6	5278.3	5371.4	5466.2	18
20	5189.6	5281.4	5374.6	5469.4	20
22	5192.6	5284.4	5377.7	5472.5	22
24	5195.6	5287.5	5380.8	5475.7	24
26	5198.7	5290.6	5383.9	5478.9	26
28	5201.7	5293.7	5387.1	5482.1	28
30	5204.7	5296.7	5390.2	5485.3	30
32	5207.8	5299.8	5393.4	5488.5	32
34	5210.8	5302.9	5396.5	5491.7	34
36	5213.9	5306.1	5399.7	5494.9	36
38	5216.9	5309.2	5402.8	5498.1	38
40	5220.0	5312.3	5406.0	5501.3	40
42	5223.1	5315.4	5409.1	5504.5	42
44	5226.1	5318.5	5412.3	5507.7	44
46	5229.2	5321.6	5415.4	5510.9	46
48	5232.2	5324.7	5418.6	5514.1	48
50	5235.3	5327.8	5421.8	5517.3	50
52	5238.3	5330.9	5424.9	5520.5	52
54	5241.4	5334.0	5428.1	5523.7	54
56	5244.5	5337.1	5431.2	5526.9	56
58	5247.5	5340.2	5434.4	5530.1	58
60	5250.6	5343.3	5437.5	5533.3	60

′	88°	′	88°	′	89°	′	89°
0	5533.3	30	5581.9	0	5630.8	30	5680.2
2	5536.6	32	5585.1	2	5634.1	32	5683.5
4	5539.8	34	5588.4	4	5637.4	34	5686.8
6	5543.1	36	5591.7	6	5640.7	36	5690.2
8	5546.3	38	5594.9	8	5644.0	38	5693.5
10	5549.5	40	5598.2	10	5647.3	40	5696.8
12	5552.8	42	5601.4	12	5650.6	42	5700.1
14	5556.0	44	5604.7	14	5653.9	44	5703.4
16	5559.2	46	5608.0	16	5657.1	46	5706.8
18	5562.5	48	5611.2	18	5660.4	48	5710.1
20	5565.7	50	5614.5	20	5663.7	50	5713.4
22	5568.9	52	5617.8	22	5667.0	52	5716.7
24	5572.2	54	5621.0	24	5670.3	54	5720.0
26	5575.4	56	5624.3	26	5673.6	56	5723.4
28	5578.6	58	5627.5	28	5676.9	58	5726.7
30	5581.9	60	5630.8	30	5680.2	60	5730.0

TABLE

GIVING RADII OF DEGREES OF CURVE.

0°							
′	RADIUS.	′	RADIUS.	′	RADIUS.	′	RADIUS.
0	INFINITE.	15	22918.3	30	11459.2	45	7639.49
1	343775.	16	21485.9	31	11089.6	46	7473.42
2	171887.	17	20222.1	32	10743.0	47	7314.41
3	114592.	18	19098.6	33	10417.5	48	7162.03
4	85943.7	19	18093.4	34	10111.1	49	7015.87
5	68754.9	20	17188.8	35	9822.18	50	6875.55
6	57295.8	21	16370.2	36	9549.34	51	6740.74
7	49110.7	22	15626.1	37	9291.29	52	6611.12
8	42971.8	23	14946.7	38	9046.75	53	6486.38
9	38197.2	24	14323.6	39	8814.78	54	6366 26
10	34377.5	25	13751.0	40	8594.41	55	6250.51
11	31252.3	26	13222.1	41	8384.80	56	6138.90
12	28647.8	27	12732.4	42	8185.16	57	6031.20
13	26444.2	28	12277.7	43	7994.81	58	5927.22
14	24555.4	29	11854.3	44	7813.11	59	5826 76
15	22918.3	30	11459.2	45	7639.49	60	5729.65

RADII OF CURVES.

1°

′	RADIUS.	′	RADIUS.	′	RADIUS.	′	RADIUS.
0	5729.65	15	4583.75	30	3819.83	45	3274.17
1	5635.72	16	4523.44	31	3777.85	46	3243.29
2	5544.83	17	4464.70	32	3736.79	47	3212.98
3	5456.82	18	4407.46	33	3696.61	48	3183.23
4	5371.56	19	4351.67	34	3657.29	49	3154.03
5	5288.92	20	4297.28	35	3618.80	50	3125.36
6	5208.79	21	4244.23	36	3581.10	51	3097.20
7	5131.05	22	4192.47	37	3544.19	52	3069.55
8	5055.59	23	4141.96	38	3508.02	53	3042.39
9	4982.33	24	4092.66	39	3472.59	54	3015.71
10	4911.15	25	4044.51	40	3437.87	55	2989.48
11	4841.98	26	3997.49	41	3403.83	56	2963.71
12	4774.74	27	3951.54	42	3370.46	57	2938.39
13	4709.33	28	3906.64	43	3337.74	58	2913.49
14	4645.69	29	3862.74	44	3305.65	59	2889.01
15	4583.75	30	3819.83	45	3274.17	60	2864.93

2°

′	RADIUS.	′	RADIUS.	′	RADIUS.	′	RADIUS.
0	2864.93	15	2546.64	30	2292.01	45	2083.68
1	2841.26	16	2527.92	31	2276.84	46	2071.13
2	2817.97	17	2509.47	32	2261.86	47	2058.73
3	2795.06	18	2491.29	33	2247.08	48	2046.48
4	2772.53	19	2473.37	34	2232.49	49	2034.37
5	2750.35	20	2455.70	35	2218.09	50	2022.41
6	2728.52	21	2438.29	36	2203.87	51	2010.59
7	2707.04	22	2421.12	37	2189.84	52	1998.90
8	2685.89	23	2404.19	38	2175.98	53	1987 35
9	2665.08	24	2387.50	39	2162.30	54	1975.93
10	2644 58	25	2371.04	40	2148.79	55	1964.64
11	2624.39	26	2354.80	41	2135.44	56	1953.48
12	2604.51	27	2338.78	42	2122.26	57	1942.44
13	2584.93	28	2322.98	43	2109.24	58	1931.53
14	2565.65	29	2307.39	44	2096.39	59	1920.75
15	2546.64	30	2292.01	45	2083.68	60	1910.08

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3°							
′	RADIUS.	′	RADIUS.	′	RADIUS.	′	RADIUS.
0	1910.08	15	1763.18	30	1637.28	45	1528.16
1	1899.53	16	1754.19	31	1629.52	46	1521.40
2	1889.09	17	1745.29	32	1621.84	47	1514.70
3	1878.77	18	1736.48	33	1614.22	48	1508.06
4	1868.56	19	1727.75	34	1606.68	49	1501.48
5	1858.47	20	1719.12	35	1599.21	50	1494.95
6	1848.48	21	1710.56	36	1591.81	51	1488.48
7	1838.59	22	1702.10	37	1584.48	52	1482.07
8	1828.82	23	1693.72	38	1577.21	53	1475.71
9	1819.14	24	1685.42	39	1570.01	54	1469.41
10	1809.57	25	1677.20	40	1562.88	55	1463.16
11	1800.10	26	1669.06	41	1555.81	56	1456.96
12	1790.73	27	1661.00	42	1548.80	57	1450.81
13	1781.45	28	1653.01	43	1541.86	58	1444.72
14	1772.27	29	1645.11	44	1534.98	59	1438.68
15	1763.18	30	1637.28	45	1528.16	60	1432.69

4°							
′	RADIUS.	′	RADIUS.	′	RADIUS.	′	RADIUS.
0	1432.69	15	1348 45	30	1273.57	45	1206.57
1	1426.74	16	1343.18	31	1268.87	46	1202.36
2	1420.85	17	1337.96	32	1264.21	47	1198.17
3	1415.01	18	1332.77	33	1259.58	48	1194.01
4	1409.21	19	1327.63	34	1254.98	49	1189.88
5	1403.46	20	1322.53	35	1250.42	50	1185.78
6	1397.76	21	1317.46	36	1245.89	51	1181.71
7	1392.10	22	1312.43	37	1241.40	52	1177.66
8	1386.49	23	1307.45	38	1236.94	53	1173.65
9	1380.92	24	1302.50	39	1232.51	54	1169 66
10	1375.40	25	1297.58	40	1228.11	55	1165.70
11	1369.92	26	1292.71	41	1223.74	56	1161.76
12	1364.49	27	1287.87	42	1219.40	57	1157.85
13	1359.10	28	1283.07	43	1215.09	58	1153.97
14	1353.75	29	1278.30	44	1210.82	59	1150.11
15	1348.45	30	1273.57	45	1206.57	60	1146.28

RADII OF CURVES.

5°

′	RADIUS.	′	RADIUS.	′	RADIUS.	′	RADIUS.
0	1146.28	15	1091.73	30	1042.14	45	996.87
1	1142.47	16	1088.28	31	1039.00	46	993.99
2	1138.69	17	1084.85	32	1035.87	47	991.13
3	1134.94	18	1081.44	33	1032.76	48	988.28
4	1131.21	19	1078.05	34	1029.67	49	985.45
5	1127.50	20	1074.68	35	1026.60	50	982.64
6	1123.82	21	1071 34	36	1023.55	51	979.84
7	1120.16	22	1068.01	37	1020.51	52	977 06
8	1116.52	23	1064.71	38	1017.49	53	974.29
9	1112.91	24	1061.43	39	1014.50	54	971 54
10	1109.33	25	1058.16	40	1011.51	55	968.81
11	1105.76	26	1054.92	41	1008.55	56	966 09
12	1102.22	27	1051.70	42	1005.60	57	963.39
13	1098.70	28	1048.48	43	1002.67	58	960.70
14	1095.20	29	1045.31	44	999.76	59	958.02
15	1091.73	30	1042.14	45	996.87	60	955.37

6°

′	RADIUS.	′	RADIUS.	′	RADIUS.	′	RADIUS.
0	955.37	15	917.19	30	881.95	45	849.32
1	952.72	16	914.75	31	879.69	46	847.23
2	950.09	17	912.33	32	877.45	47	845.15
3	947.48	18	909.92	33	875.22	48	843.08
4	944.88	19	907.52	34	873.00	49	841.02
5	942.29	20	905.13	35	870.79	50	838.97
6	939.72	21	902.76	36	868.60	51	836.93
7	937.16	22	900.40	37	866.41	52	834.90
8	934.62	23	898.05	38	864.24	53	832.89
9	932.09	24	895.71	39	862.07	54	830.88
10	929.57	25	893.39	40	859.92	55	828.88
11	927.07	26	891.08	41	857.78	56	826.89
12	924.58	27	888.78	42	855.65	57	824.91
13	922.10	28	886.49	43	853.53	58	822.93
14	919.64	29	884.21	44	851.42	59	820.97
15	917.19	30	881.95	45	849.32	60	819.02

7°							
′	RADIUS.	′	RADIUS.	′	RADIUS.	′	RADIUS.
0	819.02	15	790.81	30	764.49	45	739.86
1	817.08	16	789.00	31	762.80	46	738.28
2	815.14	I7	787.96	32	761.11	47	736 70
3	813.22	18	785.40	33	759.43	48	735.13
4	811.30	19	783.62	34	757.76	49	733.56
5	809.40	20	781.84	35	756.10	50	732.01
6	807 50	21	780.07	36	754.45	51	730.45
7	805.61	22	778.31	37	752.80	52	728.91
8	803.73	23	776.55	38	751.16	53	727.37
9	801.86	24	774.81	39	749.52	54	725.84
10	800.00	25	773.07	40	747.89	55	724.31
11	798.14	26	771.34	41	746.27	56	722.79
12	796.30	27	769.61	42	744.66	57	721.28
13	794 46	28	767.90	43	743.06	58	719.77
14	792.63	29	766.19	44	741.46	59	718.27
15	790.81	30	764.49	45	739.86	60	716.78

8°

′	RADIUS.	′	RADIUS.	′	RADIUS.	′	RADIUS.
0	716.78	15	695.09	30	674.69	45	655.45
1	715.29	16	693.70	31	673.37	46	654.20
2	713.81	17	692.30	32	672.06	47	652.96
3	712.33	18	690.91	33	670.75	48	651.73
4	710.87	19	689.53	34	669.45	49	650.50
5	709.40	20	688.16	35	668.15	50	649.27
6	707.95	21	686.78	36	666.86	51	648.05
7	706.49	22	685.42	37	665.57	52	646.84
8	705.05	23	684.06	38	664.29	53	645.63
9	703.61	24	682 70	39	663.01	54	644.42
10	702.18	25	681.35	40	661.74	55	643.22
11	700.75	26	680.01	41	660.47	56	642.02
12	699.33	27	678.67	42	659.21	57	640.83
13	697.91	28	677.34	43	657.95	58	639.64
14	696.50	29	676.01	44	556.69	59	638.46
15	695.09	30	674.69	45	655.45	60	637.28

9°

′	RADIUS.	′	RADIUS.	′	RADIUS.	′	RADIUS.
0	637.28	15	920.09	30	603.81	45	588.36
1	636.10	16	618.97	31	602.75	46	587.36
2	634.93	17	617.87	32	601.70	47	586.36
3	633.76	18	616.76	33	600.65	48	585.36
4	632.60	19	615.66	34	599.61	49	584.37
5	631.44	20	614.56	35	598.57	50	583.39
6	630.29	21	613.47	36	597.53	51	582.40
7	629.14	22	612.38	37	596.50	52	581.42
8	627.99	23	611.30	38	595.47	53	580.44
9	626.85	24	610.21	39	594.44	54	579.47
10	625.71	25	609.14	40	593.42	55	578.49
11	624.58	26	608.06	41	592.40	56	577.53
12	623.45	27	606.99	42	591.38	57	576.56
13	622.33	28	605.93	43	590.37	58	575.60
14	621.20	29	604.86	44	589.36	59	574.64
15	620.09	30	603.81	45	588.36	60	573.69

10°

′	RADIUS.	′	RADIUS.	′	RADIUS.	′	RADIUS.
0	573.69	15	559.73	30	546.44	45	533.77
1	572.73	16	558.82	31	545.58	46	532.94
2	571.78	17	557.92	32	544.71	47	532.12
3	570.84	18	557.02	33	543.86	48	531.30
4	569.90	19	556.12	34	543.00	49	530.49
5	568.96	20	555.23	35	542.15	50	529.67
6	568.02	21	554.34	36	541.30	51	528.86
7	567.09	22	553.45	37	540.45	52	528.05
8	566.16	23	552.56	38	539.61	53	527.25
9	565.23	24	551.68	39	538.76	54	526.44
10	564.30	25	550.80	40	537.92	55	525.64
11	563.38	26	549.92	41	537.09	56	524.84
12	562.47	27	549.05	42	536.25	57	524.05
13	561.55	28	548.17	43	535.42	58	523.25
14	560.64	29	547.31	44	534.59	59	522.46
15	559.73	30	546.44	45	533.77	60	521.67

11°

′	RADIUS.	′	RADIUS.	′	RADIUS.	′	RADIUS.
0	521.67	15	510.12	30	499.06	45	488.48
1	520.89	16	509.36	31	498.34	46	487.79
2	520.10	17	508.61	22	497.62	47	487.10
3	519 32	18	507.87	33	496.91	48	486.42
4	518.54	19	507 12	34	496.19	49	485.73
5	517.76	20	506 38	35	495.48	50	485.05
6	516.99	21	505.63	36	494.77	51	484.37
7	516.21	22	504.90	37	494.07	52	483.69
8	515.44	23	504.16	38	493.36	53	483.02
9	514.68	24	503.42	39	492.66	54	482.34
10	513.91	25	502.69	40	491.96	55	481.67
11	513.15	26	501.96	41	491.26	56	481.00
12	512.38	27	501.23	42	490.56	57	480.33
13	511.63	28	500.51	43	489.86	58	479.67
14	510.87	29	499.78	44	489.17	59	479.00
15	510.12	30	499.06	45	488 48	60	478.34

12°

′	RADIUS.	′	RADIUS.	′	RADIUS.	′	RADIUS.
0	478.34	15	468.61	30	459.28	45	450.31
1	477.68	16	467.98	31	458.67	46	449.72
2	477.02	17	467.35	32	458.06	47	449.14
3	476.36	18	466.72	33	457.45	48	448.56
4	475.71	19	466.09	34	456.85	49	447.97
5	475.05	20	465.46	35	456.25	50	447.39
6	474.40	21	464.83	36	455.65	51	446.82
7	473.75	22	464.21	37	455 05	52	446.24
8	473.10	23	463.59	38	454.45	53	445.67
9	472.46	24	462.97	39	453 85	54	445.09
10	471.81	25	462.35	40	453.26	55	444.52
11	471.17	26	461.73	41	452.66	56	443.95
12	470.53	27	461.11	42	452.07	57	443.38
13	469.89	28	460.50	43	451.48	58	442.81
14	469.25	29	459.89	44	450.89	59	442.25
15	468.61	30	459.28	45	450.31	60	441.68

13°

′	RADIUS.	′	RADIUS.	′	RADIUS.	′	RADIUS.
0	441.68	15	433.39	30	425.40	45	417.70
1	441.12	16	432.84	31	424.87	46	417.20
2	440.56	17	432.30	32	424.35	47	416.69
3	440.00	18	431.76	33	423.83	48	416.19
4	439.44	19	431.23	34	423.32	49	415.69
5	438.88	20	430.69	35	422.80	50	415.19
6	438.33	21	430.15	36	422.28	51	414.70
7	437.77	22	429.62	37	421.77	52	414.20
8	437.22	23	429.09	38	421.26	53	413.71
9	436.67	24	428.56	39	420.74	54	413.21
10	436.12	25	428.03	40	420.23	55	412.72
11	435.57	26	427.50	41	419.72	56	412.23
12	435.02	27	426.97	42	419.22	57	411.74
13	434.47	28	426.45	43	418.71	58	411.25
14	433.93	29	425.92	44	418.20	59	410 76
15	433.39	30	425.40	45	417.70	60	410.28

14°

′	RADIUS.	′	RADIUS.	′	RADIUS.	′	RADIUS.
0	410.28	15	403.11	30	396.20	45	389.52
1	409.79	16	402.65	31	395.75	46	389.08
2	409.31	17	402.18	32	395.30	47	388.65
3	408.82	18	401.71	33	394.85	48	388.21
4	408.34	19	401.25	34	394.40	49	387.78
5	407.86	20	400.78	35	393.95	50	387.34
6	407.38	21	400 32	36	393.50	51	386.91
7	406.90	22	399.86	37	393.05	52	386.48
8	406.42	23	399 40	38	392.61	53	386.05
9	405.95	24	398.94	39	392.16	54	385.62
10	405.47	25	398.48	40	391.72	55	385.19
11	405.00	26	398.02	41	391.28	56	384.77
12	404.53	27	397.56	42	390.84	57	384.34
13	404.05	28	397.11	43	390.40	58	383.91
14	403.58	29	396.65	44	389.96	59	383.49
15	403.11	30	396.20	45	389.52	60	383.06

RADII OF CURVES.

15°

′	RADIUS.	′	RADIUS.	′	RADIUS.	′	RADIUS.
0	383.06	15	376.82	30	370.78	45	364.93
1	382.64	16	376.41	31	370.38	46	364.55
2	382.22	17	376.00	32	369.99	47	364.16
3	381.80	18	375.60	33	369.60	48	363.78
4	381.38	19	375.19	34	369.20	49	363.40
5	380.96	20	374.79	35	368.81	50	363.02
6	380.54	21	374.38	36	368.42	51	362.64
7	380.13	22	373.98	37	368.03	52	362.26
8	379.71	23	373.57	38	367.64	53	361.89
9	379.29	24	373.17	39	367 25	54	361.51
10	378.88	25	372.77	40	366.86	55	361·13
11	378.47	26	372.37	41	366.47	56	360.76
12	378.05	27	371.97	42	366.09	57	360.38
13	377.64	28	371.57	43	365.69	58	360.01
14	377.23	29	371.18	44	365.31	59	359.64
15	376.82	30	370.78	45	364.93	60	359.27

16°

′	RADIUS.	′	RADIUS.	′	RADIUS.	′	RADIUS.
0	359.27	15	353.77	30	348.45	45	343.29
1	358.89	16	353.41	31	348.10	46	342.95
2	358.52	17	353.05	32	347.75	47	342.61
3	358.15	18	352.70	33	347.40	48	342.27
4	357.78	19	352.34	34	347.06	49	341.93
5	357.42	20	351.98	35	346.71	50	341.60
6	357.05	21	351.62	36	346.37	51	341.26
7	356.68	22	351.27	37	346.02	52	340.93
8	356.31	23	350.91	38	345.68	53	340.59
9	355.95	24	350.56	39	345.33	54	340.26
10	355.59	25	350.21	40	344.99	55	339.93
11	355.22	26	349.85	41	344.65	56	339.59
12	354.86	27	349.50	42	344.31	57	339.26
13	354.50	28	349.15	43	343.97	58	338.93
14	354.13	29	348.80	44	343.63	59	338.60
15	353.77	30	348.45	45	343.29	60	338.27

RADII OF CURVES.

17°

′	RADIUS.	′	RADIUS.	′	RADIUS.	′	RADIUS.
0	338.27	15	333.41	30	328.68	45	324.09
1	337.94	16	333.09	31	328.37	46	323.79
2	337.62	17	332 77	32	328.06	47	323.49
3	337·29	18	332.45	33	327.75	48	323 18
4	336.96	19	332.13	34	327.44	49	322.89
5	336.64	20	331.82	35	327.14	50	322 59
6	336.31	21	331.50	36	326.83	51	322.29
7	335.99	22	331.18	37	326.52	52	321 99
8	335.66	23	330.87	38	326.22	53	321.69
9	335.34	24	330.56	39	325.91	54	321.39
10	335.01	25	330.24	40	325.60	55	321.10
11	334.69	26	329.93	41	325.30	56	320.80
12	334.37	27	329.62	42	325.00	57	320.51
13	334.05	28	329.30	43	324.70	58	320.21
14	333.73	29	328.99	44	324.39	59	319.92
15	333.41	30	328.68	45	324.09	60	319.62

18°

′	RADIUS.	′	RADIUS.	′	RADIUS.	′	RADIUS.
0	319.62	15	315.28	30	311.06	45	306.95
1	319.33	16	315.00	31	310.78	46	306.68
2	319.04	17	314.71	32	310.50	47	306.41
3	318.74	18	314.43	33	310.23	48	306.14
4	318.45	19	314.14	34	309.95	49	305.87
5	318.16	20	313.86	35	309.67	50	305 60
6	317.87	21	313.58	36	309.40	51	305.33
7	317.58	22	313.29	37	309.12	52	305.06
8	317.29	23	313.01	38	308.85	53	304.80
9	317.00	24	312.73	39	308.58	54	304.53
10	316.71	25	312.45	40	308.30	55	304.27
11	316.43	26	312.17	41	308.03	56	304.00
12	316.14	27	311.89	42	307.76	57	303.73
13	315.85	28	311.61	43	307.49	58	303.47
14	315.57	29	311.33	44	307.22	59	303.21
15	315.28	30	311.06	45	306.95	60	302.94

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19°

′	RADIUS.	′	RADIUS.	′	RADIUS.	′	RADIUS.
0	302.94	15	299.04	30	295.25	45	291.55
1	302.68	16	298.79	31	295.00	46	291.30
2	302.42	17	298.53	32	294.75	47	291.06
3	302.16	18	298.28	33	294.50	48	290.82
4	301.89	19	298.02	34	294.25	49	290.58
5	301.63	20	297.77	35	294.00	50	290 23
6	301.37	21	297.51	36	293.76	51	290.09
7	301.11	22	297.26	37	293.51	52	289.85
8	300.85	23	297.01	38	293.26	53	289.61
9	300.59	24	296.75	39	293.01	54	289.37
10	300.33	25	296 50	40	292.77	55	289 13
11	300.07	26	296.25	41	292.52	56	288.89
12	299.82	27	296.00	42	292.28	57	288.65
13	299.56	28	295.75	43	292.03	58	288.41
14	299.30	29	295.50	44	291.79	59	288.18
15	299.04	30	295.25	45	291.55	60	287.94

RADII OF CURVES.

20°

′	RADIUS.	′	RADIUS.	′	RADIUS.	′	RADIUS.
0	287.94	15	284.42	30	280.99	45	277.64
1	287.70	16	284 20	31	280.76	46	277.42
2	287.46	17	283.96	32	280.54	47	277.20
3	287 23	18	283 73	33	280.31	48	276.98
4	286.99	19	283.50	34	280.09	49	276.76
5	286 76	20	283.27	35	279.86	50	276.54
6	286.52	21	283.04	36	279.64	51	276.32
7	286 29	22	282.81	37	279.42	52	276.10
8	286.05	23	282.58	38	279.19	53	275.89
9	285 82	24	282.35	39	278.97	54	275 67
10	285.58	25	282.12	40	278.75	55	275.45
11	285.35	26	281.89	41	278 52	56	275.23
12	285.12	27	281.67	42	278.30	57	275.02
13	284.88	28	281.44	43	278.08	58	274.80
14	284.65	29	281.21	44	277.86	59	274.58
15	284.42	30	280.99	45	277.64	60	274.37

21°

′	RADIUS.	′	RADIUS.	′	RADIUS.	′	RADIUS.
0	.	15	271.18	30	268.06	45	265.02
1	.	16	270.97	31	267.86	46	264.82
2	273.94	17	270.76	32	267.65	47	264.62
3	273 73	18	270.55	33	267.45	48	264.42
4	273.51	19	270.34	34	267.24	49	264.22
5	273.30	20	270.13	35	267.04	50	264.02
6	273.08	21	269.92	36	266.84	51	263.82
7	272.87	22	269.71	37	266.63	52	263.62
8	272.66	23	269.51	38	266.43	53	263.42
9	272.45	24	269.30	39	266.23	54	263.22
10	272.23	25	269.09	40	266.02	55	263.03
11	272.02	26	268.89	41	265.82	56	262.83
12	271.81	27	268.68	42	265.62	57	262.63
13	271.60	28	268.47	43	265.42	58	262.44
14	271.39	29	268.27	44	265.22	59	262.24
15	271.18	30	268.06	45	265.02	60	262.04

22°							
′	RADIUS.	′	RADIUS.	′	RADIUS.	′	RADIUS.
0	262.04	15	259.13	30	256.29	45	253.51
1	261.85	16	258.94	31	256.10	46	253.33
2	261.65	17	258.75	32	255.92	47	253.14
3	261.45	18	258.56	33	255.73	48	252.96
4	261.26	19	258.37	34	255.54	49	252.78
5	261.06	20	258.18	35	255.36	50	252.60
6	260.87	21	257.99	36	255.17	51	252 42
7	260.68	22	257.80	37	254.99	52	252.24
8	260.48	23	257.61	38	254.80	53	252.05
9	260.29	24	257.42	39	254.62	54	251.87
10	260.10	25	257.23	40	254.43	55	251.69
11	259.90	26	257.04	41	254.25	56	251.51
12	259.71	27	256.85	42	254.06	57	251.33
13	259.52	28	256.67	43	254.88	58	251.15
14	259.33	29	256.48	44	253.70	59	250.97
15	259.13	30	256.29	45	253.51	60	250.79

23°							
′	RADIUS.	′	RADIUS.	′	RADIUS.	′	RADIUS.
0	250.79	15	248.13	30	245.53	45	242.98
1	250.61	16	247.96	31	245.36	46	242.81
2	250.43	17	247.78	32	245.19	47	242.64
3	250.26	18	247.61	33	245.02	48	242.48
4	250.08	19	247.43	34	244.84	49	242.31
5	249.90	20	247.26	35	244.67	50	242.14
6	249.72	21	247.08	36	244.50	51	241.98
7	249.54	22	246.91	37	244.33	52	241.81
8	249.37	23	246.74	38	244.16	53	241.64
9	249.19	24	246.56	39	243.99	54	241.48
10	249.01	25	246.39	40	243.83	55	241.31
11	249.84	26	246.22	41	243.66	56	241.15
12	248.66	27	246.04	42	243.49	57	240.98
13	248.48	28	245.87	43	243.32	58	240.82
14	248.31	29	245.70	44	243.15	59	240.65
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